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13. ABSTRACT (Maximum 200 words)

The terahertz part of the electromagnetic spectrum is technology poor. An examination of the underlying device physics associated with the technologies that border this part of the spectrum, suggest that it marks a transition regime between transport electronics at the low frequency end (microwave frequencies) to quantum transition devices like lasers on the high frequency end (infrared). Quantum transport devices, as the name implies, embraces both transport physics and quantum transitions.
The objectives of this research were to explore terahertz loss and gain in order to establish the principles for developing a solid-state terahertz oscillator based on multi-quantum well superlattices.
Key results were the following
- Resonant photon assited transport in semiconductor superlattices
- Harmonic generation from electrically biased superlattices
- Measurements of terahertz loss and gain in electrically biased superlattices.

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Sincerely,

S. James Allen

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Terahertz Gain and Loss in Semiconductor Quantum Structures

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Statement of the Problem

The terahertz part of the electromagnetic spectrum is technology poor. An examination of the underlying device physics associated with the technologies that border this part of the spectrum, suggest that it marks a transition regime between transport electronics at the low frequency end (microwave frequencies) to quantum transition devices like lasers on the high frequency end (infrared). Quantum transport devices, as the name implies, embraces both transport physics and quantum transitions. Indeed early experiments by us, at terahertz frequencies, revealed a variety of phenomena normally only found in superconducting electronics and described as photon assisted transport.

The objectives of this research were to explore terahertz loss and gain in order to establish the principles for developing a solid-state terahertz oscillator based on multi-quantum well superlattices.

Summary of the most important results.

During the performance period the following issues were experimentally addressed.

Resonant photon assisted transport was explored and documented. By integrating a Schottky detector along side a sequential resonant tunneling superlattice, the photon assisted currents could be normalized to Schottky detector response. By sweeping the terahertz radiation from the Free-electron Lasers, various photon assisted processes are shown to resonate when the radiation frequency also coincided with the intersuband transions in a given quantum well.

Terahertz harmonic generation was measured from electrically biased semiconductor superlattices. In experiments carried out in collaboration with researchers from the University of Regensburg, single mesas were excited in a corner cube. More important for the future exploitation of these systems, techniques were developed for fabricating quasi-optical arrays of micron size superlattice diodes. Third harmonic generation was measured in unbiased arrays, while second harmonics were produced when the array was electrically biased. Non-linear quantum transport models were successfully used to describe the response.

Terahertz loss and gain was measured by integrating the quasi-optical arrays in terahertz cavities. Measurements were carried out over a broad frequency range – 300 GHz to 2.5 THz. Changes in the cavity loss were measured and modeled using theories of the terahertz conductance in electrically biased superlattices. Agreement with the measured results could only be obtained if the formation of electric field domains was properly modeled. These results point to a potentially important approach to the development of a terahertz solid-state oscillator. They also highlight a critical issue, the requirements of a uniform internal electric field and the suppression of electric field domains.

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Inventions. None filed.